# Agronomy and agricultural history in England

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## Introduction

In this paper I want to show how important agronomy is to understanding the agricultural history of England. I am not going to consider the history of the science of agronomy: that would be impossible in such a short paper, and in any case several surveys already exist (Russell, 1966; Fussell, 1971; Ambrosoli, 1997). Rather, I want to show how the science of agronomy can help us understand English agricultural history, and look at two episodes in the agricultural history of England: the alleged exhaustion of the soil in medieval England, and the phenomenon known as the agricultural revolution of the $17^{th}$, $18^{th}$, and $19^{th}$ centuries. Both these developments in English agricultural history have been regarded as turning points or decisive and significant breaks with the past. The first was significant because it indicated the breakdown of the stable ecology of medieval farming systems, and the second, because it also indicated a change in the ecological equilibrium, but this time in a very positive way, in that new crop rotations enabled crop output to increase without adverse consequences.

Both these episodes reflect a dilemma as old as agriculture itself: how to expand the output of food without jeopardising the ecological equilibrium. In order to remain sustainable, most arable systems before the $19^{th}$ century needed a period of fallow in the crop rotation. The fallow had many functions, but the two most important were the cleaning of perennial weeds, and the accumulation of nitrates in the soil through bacterial action. If the cropped area was expanded in an attempt to grow more food, and the fallow area reduced, then less nitrogen could be fixed and there was a danger that weeds would get out of control. Extending the arable by encroaching onto pasture or meadow reduced the fodder available for livestock and therefore reduced the amount of nitrogen that could be circulated from the pasture to the arable through animals. Fewer livestock could also mean a reduction in traction and therefore a reduced ability to perform the basic operations of arable husbandry. Increasing livestock numbers could only be achieved by replacing arable with pasture and therefore reducing the area of food crops, or by overstocking pastures leading to their degradation.

While most agricultural historians are aware of these constraints to food production, some are guilty of a rather simplistic view of soil fertility. ‘Fertility’ is conceptualised as a stock of nutrients ‘mined’ by growing plants and can only be replenished by manure which is a function of the number of animals. It is implicitly assumed that animals somehow ‘make’ manure whereas in fact they recycle crop nutrients, especially nitrogen, and their main role is processing and moving nitrates around the farm. There are a wide range of forms of organic nitrogen, which vary in the rate at which they degrade into mineral nitrogen. Furthermore, the ability of plants to make use of available nitrogen depends on a multitude of factors, ranging from the acidity of the soil, the degree of leaching, competition from weeds, and the impact of soil structure upon the root system of the crop (Shiel, 1991).

## Soil exhaustion in medieval England

One the most influential interpretations of medieval English agriculture was developed by Postan (1966). He argued that rapid population growth during the 12$^{th}$ century led to the colonisation of land that was physically marginal for cultivation and became ecologically unstable. The extension of arable at the expense of pasture reduced the quantity of livestock available to provide

| | N | P | K |
|---|---|---|---|
| Exports | 521-706 | 104-137 | 135-184 |
| Imports | | | |
| Hay | | 8.5 | 85.4 |
| Weathering | | 6.85-68.5 | 68.5-2740 |
| **Total imports** | 912 | 15-77 | 154-2825 |
| **Balance** | positive | negative | positive |

Source: Newman and Harvey (1997).

Table 1
Estimates of nitrogen, phosphorous and potassium balances (kg/year) on the Manor of Cuxham (UK), 1320-40.

traction and manure. In turn, this led to a nitrogen shortage, soil deterioration, and falling yields. The evidence for this thesis came mainly from the manorial accounts of the estates of the Bishop of Winchester in southern England (Titow, 1972), which show a sustained fall in the yields of spring-sown cereals during the second half of the 13th century. Evidence from taxation returns of 1342 seems to corroborate this as they record quite large areas of arable land being withdrawn from cultivation, presumably because soils were becoming exhausted, while demographic evidence suggests that on some English manors population was declining in the early 14th century: before the great crisis of the Black Death in 1348-49, presumably in response to a shortage of food.

Despite this evidence, exhaustion of the soil has been inferred rather than measured (Campbell, 2000). However, a recent study by an agronomist and an historian (Newman and Harvey, 1997) makes an attempt to estimate the nutrient balance in the soil, albeit for just one manor. The accounts for the manor record the areas under crops, the quantity of seed sown, the yields of crops, and the destinations of the harvested crops. Some, such as wheat, were sold, but others, such as oats and legumes, were entirely consumed on the manor. The accounts also record the quantities of livestock, the numbers that were added through birth or purchase, and the numbers that were lost through slaughter, disease, or sale. Modern evidence of the quantities of nutrients in various crops is used to estimate the total quantities of nutrients contained in the various parts of each crop.

The findings of this study are summarised in Table 1. 'Exports' are the losses of N, P and K from the manor when crops were sold or otherwise taken away from the village. The lower figures are the net exports from the manor and the upper figure is these net exports plus those nutrients contained in the food consumed by people in the village. Thus the higher figure assumes these nutrients are lost to the village, whereas the lower figure assumes that they are recycled. Estimates of the 'imports' of nitrogen into the farming system of the manor derive from purchases of hay and fixation by legume crops such as peas and beans, although these sources only balanced about one third of the nitrogen losses. Other likely inputs of nitrogen are from legumes in pasture and meadow, though cyanobacteria in cropland and fallow and through free-living bacteria in the soil. Calculating the imports of P and K is more problematic. The only certain source of inputs is through the hay that the manor purchased, which was much more significant for K than P, and through weathering of rock material which was much faster for K than for P.

The result of balancing imports against exports is shown on the bottom line of Table 1. Nitrogen and potassium were accumulated but phosphorous lost. In the absence of any information about the stock of phosphorous on the manor, we cannot say that the soil was 'exhausted' but we can say that there was a continuing net loss of nutrients. During the first half of the 14$^{th}$ century the trend of cereal yields was downward, so it is possible that crops were deficient in phosphorous. But perhaps more important than this specific finding is that the methods used enable us to have a much clearer understanding of a medieval agricultural system. Their work enables us to understand the basis of the ecological equilibrium and the points where the system was vulnerable, and, building on the work of earlier authors viewing medieval agriculture in ecological terms (Cooter, 1978; Pretty, 1990), they correct simplistic notions of a declining fertility based on nitrogen depletion.

## The agricultural revolution

Historians have long debated the English agricultural revolution. There are at least seven different arguments for an agricultural revolution in the period from the 16th – 19th centuries, which stem partly from disagreements over the concept of an agricultural revolution and partly from disagreements over empirical evidence (Overton, 1996a,b; Béaur, 1998; Campbell and Overton, 2005). A more explicit consideration of agronomy can help put these various agricultural revolutions in perspective, and provide a framework for understanding how change came about.

The major claim for an early agricultural revolution comes from Kerridge (1967). Although he considers a number of ways in which output increased (fen drainage, new fertilisers, and 'floating' water-meadows, for example) he places most emphasis on what he calls 'up and down husbandry' or 'convertible husbandry'. In this system the distinction between permanent grass and permanent arable is broken. At its simplest, pasture was broken up and cropped with corn for a few years, and then the land was allowed to revert to grass for some time, perhaps over twenty years, but more sophisticated systems would have much shorter grass leys of a year or two. Kerridge has made much of convertible husbandry, and considers the main period of its spread was between 1590 and 1660.

It is not clear from the evidence that the ley farming of this period was the same as that practised several centuries later (Overton, 1991, 293-4), and some historians consider the impact of convertible husbandry farming on yields would have been minimal. After the Black Death of 1348-9 a reduction in population saw much arable land revert to pasture. Experiments have shown that when grass is sown on old arable land the nitrogen content more than doubles in a hundred years (Jenkinson, 1988, p. 589-91). When the grassland was ploughed up under pressure of a rising population in the 16th century, the store of nitrogen released could have had a dramatic short-term influence on the yield of cereal crops. Nevertheless, within a period of a few years, yields would have fallen back to their previous levels as the amount of organic matter decreased, and the soil became more acid because of leaching and the production of acids from the decay of organic matter. Thus the development of convertible husbandry from the mid-16th century could be interpreted as a means of cashing in on reserves of nitrogen under permanent pasture for short-term gain. Indeed, there is some evidence of a retreat from 'up and down' husbandry in the midlands in the later

17th century once these gains had been made and yields were probably starting to fall (Broad, 1980). It was also difficult to establish a grass ley: ‘to make a pasture breaks a man, to break a pasture makes a man’ (Moore, 1946, p. 17), especially when the grass seed available to many farmers consisted of little more than the sweepings from the hay barn.

Despite the findings at Cuxham reported above it is likely that nitrogen was the limiting factor in most husbandry systems producing cereals until the 19th century (Shiel, 1991). One way to gain a greater understanding of the agricultural revolution therefore, is to view it in terms of the supply of nitrogen to growing crops. More nitrogen can be made available by exploiting existing supplies of nitrogen; by making more nitrogen already in the soil available to crops; by conserving nitrogen supplies; and by adding new supplies of nitrogen to the soil.

# Availability of nitrogen

## *Exploiting existing sources of nitrogen*

The easiest way of exploiting existing stores of nitrogen was to plough up permanent pasture, but without other changes this would merely give a temporary boost to nitrogen supplies and reduce supplies of fodder. However, the lost pasture was replaced by new fodder crops such as turnips and clover, and the root crops were instrumental transforming poor quality permanent pasture on light land into productive arable land. They did this by taking more nutrients from the soil than cereal crops, and, since their roots were deeper in the ground, from a different level in the soil. These nutrients could then be recycled, either as manure, or through crop residues left in the soil. Root crops were also important (along with other new fodder crops such as clover) because they were a higher yielding form of fodder than the grass on permanent pastures. The exact difference in yield (in terms of food-value) is hard to estimate but in the early years of the present century an average turnip crop gave 70% more starch per hectare than an average hay crop and 40% more protein; clover hay 20% more starch per hectare and 80% more protein (Tivy, 1990).

## *Making more existing nitrogen available*

Another way to make more nitrogen available to crops was to increase the rate at which organic nitrogen decayed into mineral nitrogen. The micro-organisms in the soil responsible for this require warmth, oxygen, water, and a moderate acidity. Thus reducing soil acidity through the application of lime, for example, could produce a sudden spurt in nitrogen mineralisation. Farmers were well aware of the benefits of adding lime to the soil, as burnt lime, and later, as ground lime. Marl was another substance frequently added to the soil. It was a mixture of clay and calcium carbonate and was much used both to improve soil structure and reduce acidity.

Soil drainage was the most important way of improving soil structure. Successful underdraining on a large scale had to wait until the 19th century with the introduction of the tile drain. Before then ridge and furrow was the principal means of surface drainage, but from the 17th century onwards hollow drains seem to have been more frequently employed, whereby stones or bushes were put into trenches and covered with soil. It is likely that the effectiveness of underdraining before the advent of tile drains in the mid-19th century has been underestimated, since there are examples from the Midlands and East Anglia of quite dramatic increases in crop yields following underdraining in the late 18th and early 19th centuries.

## *Conserving nitrogen supplies*

More nitrogen could be added to the soil if existing stocks were conserved by managing supplies of manure more effectively. Since livestock eat during the day but defecate and urinate during both day and night, grazing animals on pasture during the day and putting them on the arable at night effectively moved nitrogen from pasture to arable. This was a feature of the East Anglian fold course system (Overton, 1996a, p. 29), but a more effective way of conserving nitrogen stocks was to integrate grass and grain in rotations. Most efficient of all was the stall-feeding of livestock, particularly cattle, so that their manure could be collected and deposited exactly where it was needed. Stall-fed bullocks were not unknown in the 17th century (Overton and Campbell, 1992), but it was not until the widespread cultivation of fodder crops, especially root crops, that the practice became common.

### *Adding new supplies of nitrogen to the soil*

The most important source of new nitrogen was from leguminous crops. The introduction of new legumes, especially clover, from the 17th century dramatically improved the amount of nitrogen fixed from the air. For northern Europe it has been estimated that the introduction of new leguminous crops like clover increased the total nitrogen supply by around 60% (Chorley, 1981) and it likely to have been higher for England. Various clovers are indigenous to England, and probably formed part of natural grassland in some parts of the country. The introduction of sown clover leys is, however, a 17th century phenomenon: as early as the 1620s there is evidence of clover seed being imported from the Low Countries (Ambrosoli, 1997). The first direct evidence of farmers sowing clover comes from the mid-17th century, and the crop advanced on a wide front across the country (Overton, 1985). By the 1830s, when the first nationwide statistics for clover and 'seeds' are available it was accounting for over 30% of the arable area in some counties.

## Reducing fallow

Turnips and clover also helped to reduce the area of fallow. Turnips grew quickly and could smother weeds with their large leaves. If they were grown in rows, and hoed, then weeds could be controlled.

The replacement of the bare fallow by a root crop would reduce leaching and intercept the nitrogen that otherwise would be lost. Furthermore if the roots were fed to livestock in situ then soil nitrogen would be recycled efficiently. In the 1690s about 20% of arable land in England was fallow, by the 1830s, 12%, and by the 1870s, 4%. The correlation on a county basis between the proportions of land under fallow and under turnips in the 1830s is a remarkable -0.84: clear evidence that turnips replaced fallows (Overton, 1996a, p. 101).

## The Norfolk four-course rotation

The integration of grass and grain and the introduction of fodder crops came together in a rotation known as the Norfolk four-course. An attempt to model the output from such a system suggests that cereal output was over 60% higher compared with an equivalent area under permanent arable and permanent pasture and no fodder crops (Shiel, 1991). In view of the significance of this rotation, and the principles it embodies, it is worth asking how it came about and the role of contemporary ideas about agronomy in its development.

Contemporary writers enthused about clover, pointing to its cultivation in the Low Countries as evidence of its value. Some writers recognised that cereal crops following clover would benefit, as Blith, (1652, p. 184) put it: 'after the three or four first years of Clovering, it will so frame the earth, that it will be very fit to Corn again, which will be a very great advantage.' Until the 18$^{th}$ century most writers considered turnips a garden crop, but Lawrence (1726, p. 109) considered turnips were one of the 'chief treasures' of the farmer, responsible for great profits'. However, while we know that some gentry farmers took great interest in these new crops, the vast majority of farmers new nothing of the writings about them and learnt about them from their neighbours (Overton, 1985).

The Norfolk four course rotation took well over a hundred years to develop. Turnips and clover were first grown by farmers for livestock fodder in the early 17$^{th}$ century, but it was not until after the mid-18$^{th}$ century that the rotation was fully developed and being

| | 1250-1349 | 1350-1449 | 1584-1640 | 1660-1739 | 1836 | 1854 |
|---|---|---|---|---|---|---|
| % Grain | | | | | | |
| Wheat *a* | 19 | 18 | 29 | 20 | 48 | 49 |
| % Sown as *b* | | | | | | |
| Grain | 87 | 87 | 87 | 84 | 49 | 52 |
| Legumes | 14 | 13 | 9 | 14 | 27 | 24 |
| Clover | 0 | 0 | 0 | 2 | 25 | 21 |
| Turnips | 0 | 0 | 0 | 7 | 24 | 22 |
| Livestock ratio *c* | 80 | 90 | 128 | 175 | | 153 |
| Draught beasts *d* | 20 | 15 | 35 | 28 | | 28 |
| Grain yields | | | | | | |
| Wheat *e* | 14 | 11 | 14 | 14 | 21 | 27 |
| WACY *f* | 10 | 8 | 8 | 9 | 19 | 23 |

Source: Overton (1996b).

Table 2
Trends in agricultural production in Norfolk (UK), 1250-1854.
*a* As a percentage of wheat, rye, maslin, barley, and oats
*b* Area sown with arable crops excluding fallow
*c* Livestock units per 100 cereal hectares
*d* Oxen and horses per 100 sown hectares
*e* Hectolitres per hectare
*f* Weighted Aggregate Cereal Yield

practised on farms. Table 2 shows some of the key elements in the agricultural development of Norfolk and Suffolk, the heartland of the agricultural revolution, and it is not until the 19th century that turnips and clover are grown on a scale to suggest that the Norfolk four-course was common (Campbell and Overton, 1993). Before the mid-18th century turnips were commonly grown as a catch crop and neither drilled nor hoed (Overton, 1996a, p. 99-101). It was just as these crops were becoming more common, in the latter half of the 18th century, that contemporary literature on agronomy began to offer useful practical advice, based upon empirical observation and scientific experiment, for example by Arthur Young and William Marshall (Brunt, 2003; Horn, 1982). The principal element of the agricultural revolution therefore, owed little to contemporary science and was the result of a century of trial and error and adaption. Indeed an increase in cereal yields was probably an unintended outcome, in that the introduction of turnips and clover were initially to provide fodder rather than to improve cereal output.

# Conclusion

In this paper I have tried to show how by adopting a perspective from agronomy we can gain a clearer understanding of two of the key turning points in the history of English agriculture. This is not to deny the importance of many other influences on agricultural development. While agronomy helps us understand why farming was carried out as it was and how it changed, it cannot explain why that change came about when it did.

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